Smart Bike Lock

Team 33

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Customer Background

The Purdue Research Foundation wishes to create a system where individuals can introduce their personal bikes into a ride-sharing program with the use of a smart lock, or “A-lock”, that is operated via Bluetooth. A previous team was tasked with developing this "A-lock" and was successful in developing a locking mechanism and a housing concept for the case.

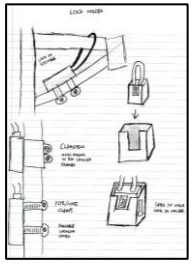
Problem Statement / Scope of Work

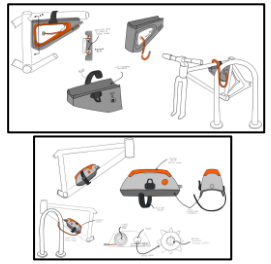
Team 33 was tasked with designing a Bluetooth enabled, compact solution for the A-Lock, while implementing the previous year’s lock concept. The team was focused on the visual appeal and the overall functionality of the A-Lock. While considering security and theft, the lock assembly had to fit multiple bike frames and use a retractable cable. The owner of the lock was to be the only one capable of detaching the assembly from the bike.

Requirements Matrix

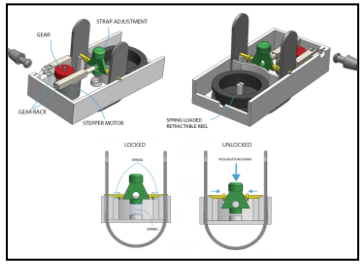
Index	Requirement	Description	Test to Verify
1	Cable Length	The length of the retractable cable must be >3ft.	Bike rack test.
2	Cable Strength	The cable must be resistant to cutting with common hand tools.	Cut test.
3	Cable Retraction	The locking cable must retract into the body of the lock.	Pull test.
4	Small Form Factor	The maximum size of the case must not exceed 8”L x 4”W x 4”H.	Mount on bike frame, then ride bike test.
5	Durable, Tamper-proof case	The material of the case must withstand impact.	Material standards and documentation.
6	Weather-Resistance	The materials of the product must show no degradation of performance in harsh conditions.	Water spray test for assembly.
7	Battery Life	Battery should last >1 week during normal usage.	Soak/usage test.
8	Bluetooth Control	Bike lock must be able to be unlocked wirelessly via Bluetooth, at up to a range of 33 ft.	BT pair, cycle test.
9	Cost	The cost of development and supplies for the project must be under $1000.	Expenditure tracking.

Experimentation / Concepts Exploration





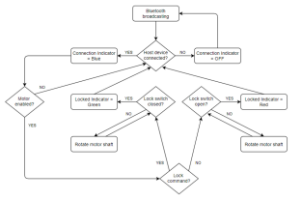
Case and Mounting Concept



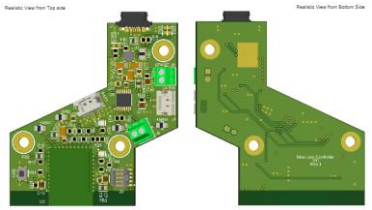
Locking Concepts

Final Design

Bike Lock Assembly



Firmware Flow Diagram



PCB Assembly

FMEA

Item Function	Potential Failure Mode	Potential Effect(s) of Failure	Severity	Potential Causes(s) of Failure	Occurrence	Current Design Controls Prevention	Current Design Controls Detection	Detection	RPN	Recommended Action(s)
Case housing to protect interior components	Someone breaks into case	Unlocks bike	8	Blunt trauma	3	High impact resistance and only the owner or customer with permission can access	Published data from manufacturer and design	2	48	No Action Required
	Break	Cracks, leaks, unlock	8	Blunt trauma	3	High strength plastic and components	Published data from manufacturer and design	2	48	No Action Required
Motor to lock and unlock cable	No rotation	Cable stuck in position	8	Contaminants, vibrations and friction	3	Mounting clip to secure to case and sealed from contaminants	Motor design and case design	2	48	Test Motor Under Operating Climate, Cycle Test
Battery to keep electrical components working	Dead Battery	Cable stuck in position, no Bluetooth control	8	Lack of customer charging	3	Voltage and current regulated management IC and protection built-in battery	Published data from manufacturer and electrical design	3	72	Operate lock 5 times a day
	Explodes	Battery damaged	8	High temperature, overcharging voltage	1	Voltage and current regulated management IC and protection built-in battery	Published data from manufacturer and electrical design	3	24	Operate lock 5 times a day

Testing

Test Name	Test Description	Results
Cable Cut Test	Perform cut tests with cable cutters wire cutters and bolt cutters on 1/4” 3/16” and 1/8” to test if each tool can cut through the cables in a reasonable amount of time. Compare results with SUS test.	PASS
Cable Extension Test	Pull the cable to full extension and allow cable to retract under spring tension to ensure cable, spool, and coil spring mechanism are not binding or getting stuck.	PASS
Repeated Extension Test	Fully extend and retract cable 50 times to test for excessive wear on components.	PASS
Cable “Whip” Test	Test to ensure cable does not retract immediately when locking mechanism is set to unlock. Cable should be manually released from pin capture. Pin should only be released when cable is pulled from lock. For safety, no “whip” action should occur when unlocking.	PASS
Lock Body Test	Ensure all components fit into and the lock body.	CONDITIONAL PASS
Cable Lock Test	Test if cable pin is captured by locking mechanism. Ensure the motor can engage and disengage the lock under its own power.	CONDITIONAL PASS
Motor Cycle Test	Use motor to lock and unlock the cable mechanism 50 times to check for stability of gear rack design and motor choice.	CONDITIONAL PASS
Strap Lock Test	Test if keyed lock securely engages with cutouts in the rubber strap. Strap must be lockable across all teeth cutouts.	PASS
Strap Fitment Test	Test fit/function of the lock on various types of bike frames. Strap must fit all bikes tested.	PASS
Electronics Thermal Test	Operate electronics under heavy charge cycle, when power dissipation is at its maximum. Check component temperatures with thermal gun, must be below 65 C.	PASS
Battery Life	Operate electronics under expected use case. Perform lock/unlock cycle 5x per day until lock is inoperable.	PASS
Wireless Range Test	Using a board marked from 0 to 90deg from center, test line-of-sight distance capability of BT.	PASS
Water Spray Test	Spray the bike lock assembly (without electronics) from all directions for 30 seconds to test for water ingress. Can water get into electronic area?	PASS
Bike Rack Test	With the lock assembly mounted to a bike frame, ensure cable lock can be locked to bike racks. Cable must be long enough to secure to a bike rack.	PASS